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Manual  
No. 1110-2-2705

31 March 1994

**Engineering and Design**  
**STRUCTURAL DESIGN OF CLOSURE STRUCTURES**  
**FOR LOCAL FLOOD PROTECTION PROJECTS**

**1. Purpose.** This engineer manual (EM) provides guidance for the structural design of closure structures for openings in levees and floodwalls of inland local flood protection projects (LFPPs). Design requirements for aluminum and steel stoplog closure structures and steel swing, miter, trolley, and rolling gate closure structures for openings in levees and floodwalls of LFPPs are addressed. This guidance provides a framework for incorporating the required elements of design execution into the design process for closure structures.

**2. Applicability.** This manual is applicable to all HQUSACE elements, major subordinate commands, districts, laboratories and field operating activities having civil works design and construction responsibilities.

FOR THE COMMANDER:

A handwritten signature in black ink, appearing to read 'William D. Brown', with a stylized flourish at the end.

WILLIAM D. BROWN  
Colonel, Corps of Engineers  
Chief of Staff

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## Chapter 1 Introduction

### 1-1. Purpose and Scope

*a. Purpose.* This engineer manual (EM) provides guidance for the structural design of closure structures for openings in levees and floodwalls of inland local flood protection projects (LFPPs).

*b. Scope.* The scope of this guidance includes the design requirements for aluminum and steel stoplog closure structures and steel swing, miter, trolley, and rolling gate closure structures for openings in levees and floodwalls of LFPPs. This guidance provides a framework for incorporating the required elements of design execution into the design process for closure structures.

### 1-2. Applicability

This manual is applicable to all HQUSACE elements, major subordinate commands, districts, laboratories, and field operating activities having civil works design and construction responsibilities.

### 1-3. References

*a.* EM 1110-2-38, Environmental Quality in Design of Civil Works Projects.

*b.* EM 1110-2-301, Guidelines for Landscape Planting at Flood Walls, Levees, and Embankment Dams.

*c.* EM 1110-2-2104, Strength Design for Reinforced-Concrete Hydraulic Structures.

*d.* EM 1110-2-2105, Design of Hydraulic Steel Structures.

*e.* EM 1110-2-2502, Retaining and Flood Walls.

*f.* EM 1110-2-2703, Lock Gates and Operating Equipment.

*g.* EM 1110-2-2906, Design of Pile Foundations.

*h.* EM 1110-2-3104, Structural and Architectural Design of Pumping Stations.

*i.* EM 1110-2-3400, Painting: New Construction and Maintenance.

*j.* Aluminum Association, Inc. 1986. "Specifications for Aluminum Structures," 900 19th Street, NW, Suite 300, Washington, DC 20006.

*k.* American Association of State Highway and Transportation Officials (AASHTO). 1989. "Standard Specifications for Highway Bridges," 14th ed., 444 North Capitol Street, NW, Suite 225, Washington, DC 20001.

*l.* American Institute of Steel Construction (AISC). 1986. "Manual of Steel Construction, Load and Resistance Factor Design (LRFD)," 1st ed., 400 North Michigan Avenue, Chicago, IL 60611.

*m.* American Institute of Steel Construction (AISC). 1989. "Manual of Steel Construction, Allowable Stress Design (ASD)," 9th ed., 400 North Michigan Avenue, Chicago, IL 60611.

*n.* American Railway Engineering Association. 1991. "1991 Manual for Railway Engineering," Volume I, Chapters 1 through 8, and Volume II, Chapters 9 through 33, 50 F Street, NW, Suite 7702, Washington, DC 20001.

### 1-4. Background

This manual was developed to provide uniform criteria for the design of closure structures for openings in levees and floodwalls of LFPPs. The development process involved reviewing and evaluating the design and performance of existing closure structures constructed throughout the Corps to identify the structures which are cost-effective and efficient in operation, and incorporating the design features of these projects into the criteria provided herein. The resulting guidance contained in this manual provides a series of design requirements and provisions that should be applied to the design of closure structures.

## Chapter 2 Design

### 2-1. Design Process

The structural design of closure structures for openings in levees and floodwalls should be planned in detail to ensure that the elements of the structural design responsibility are properly executed during the reconnaissance phase through the operations phase of projects. These elements include: coordinating the required input from the project manager, project engineer, and other engineering disciplines and functional members of the design team; incorporating general design provisions into the design process and resulting solutions which pertain to operational, functional, maintenance, aesthetics, safety, security, construction, and economical considerations; examining and comparing pertinent features of closure types, selecting the appropriate closures and suitable alternatives for particular applications, and defining the preferred general design concept which provides a basis for estimating the construction cost; and performing the required structural analyses and design of structural features and ensuring design quality through design review and other methods of verification. Appendix A provides a checklist of design functions required during each phase of the design process.

### 2-2. Design Coordination

Full coordination of the total design process should be considered as the most essential element for ensuring design quality. The structural engineer must operate within the prescribed role and functional relationships established between the structural discipline and the project manager, project engineer, engineering disciplines, and other functional elements engaged in the design process to effectuate the coordination required for the design of closures.

*a. Project manager.* Throughout the design process, the project manager is responsible for coordinating with the local sponsor, communicating input from the local interests to the project engineer and design engineers, and ensuring that the major design features of closure structures are acceptable to the local interests. The project manager must also obtain agreement with agencies or entities which own and maintain utilities and facilities which would be impacted by the construction of the closure structures. Such facilities include pipe lines, transmission lines, streets, highways, bridges, and railroads.

*b. Project engineer.* The project engineer, in managing the design of closure structures, is responsible for interacting with the project manager to obtain the agreed local sponsor requirements and acceptance of proposed design solutions for closure structures and communicating these to the functional elements engaged in the project including real estate, planning, engineering, construction, and operations.

*c. Structural engineer.* The structural engineer is responsible for coordinating with the project engineer and other engineering disciplines engaged in the design of closure structures, including civil, geotechnical, hydraulic, mechanical, coastal, environmental, construction, and operations engineers, to ensure all pertinent engineering considerations are properly integrated into the structural design.

### 2-3. General Design Provisions

General design provisions which must be integrated into the design process for the design and construction of closure structures for LFPP include operational, functional, maintenance, aesthetics, safety, security, construction, and economical considerations. These provisions must be fully and appropriately addressed in the design process and the resulting project documents.

*a. Operational.* The required lead time for closing the structures in the event of flooding is controlled by the rate of rise of the flood waters. The accuracy of advanced forecasting of flooding determines the length of time which should be scheduled for the mobilization of operations personnel and equipment required to close the structures. Also, the accuracy of forecasting determines the number of times traffic is inconvenienced by a closed structure when flooding does not occur. The scheduled time for closure of structures should include a cushion to ensure that closure is completed well before the arrival of flood waters. The required lead time and the types of operating equipment and operations personnel available to the local sponsor are the primary factors in determining the type of closure structures suitable for particular applications.

*b. Functional.* Functional requirements for facilities, such as roadways and railroads, affect the design of closure structures. Existing site topography and clearance requirements for roadways (highways and streets) and railroads are primary functional considerations which must be incorporated into the design of closure structures.

(1) Site topography. Existing grades parallel to roadways and railroads affect the required site distances along these facilities. Variation of grades along roadways and railroads affects the selection of the type of closure structures and the design of sills and supports for these facilities. For example, multiple sets of railroad tracks occurring at different grade elevations require a hinged bottom seal arrangement to provide an effective seal.

(2) Clearances.

(a) Roadways. The opening widths provided for roadways shall comply with the requirements of the American Association of State Highway and Transportation Officials (AASHTO) (1989). The width of closure openings should not be less than 30 ft for roadways with two lanes of traffic. The minimum vertical clearance between the crown of roadways and fixed overhead components of closures should not be less than 14 ft. Clearances should be coordinated and approved by the facility owner.

(b) Railroads. Minimum horizontal and vertical clearances shall not be less than that required by the AASHTO (1989). The normal minimum width of opening provided for railroads is approximately 20 ft for each set of tracks involved in the closure. Clearances should be coordinated with and approved by the facility owner.

*c. Maintenance.* Proper maintenance of closure structures is essential to the continuous satisfactory performance of the structures. The required maintenance provisions must be included in the agreement with the local sponsor. Current agreements with local sponsors require annual periodic inspections of the closure structures and the adjoining levee or floodwall. Inspections must be thorough so that any deficiencies that are critical to the function of the project are detected and promptly corrected. Designs should incorporate materials, systems, and features which are economically feasible and require minimal maintenance.

*d. Aesthetics.* The requirements for incorporating aesthetic quality into the design of LFPP have been established. EM 1110-2-38 provides guidance for aligning flood control channels, landscaping along channels, and the aesthetic treatment of channel linings. EM 1110-2-301 also provides guidance for landscaping. In some LFPP floodwalls, an open view of the waterway was made an aesthetic requirement. These projects incorporate closures with bottom hinged walls which can be

stored in the lowered position and raised for protection during flood periods.

*e. Safety.* The design of closures must include safety provisions for the public and the operations personnel. Local sponsors are responsible for the safe operation of closure structures; therefore, designers must coordinate with sponsors so that the appropriate design provisions are incorporated to ensure safe operation. General safety provisions include providing railings on the top of gates and adjacent walls for public protection and providing ladders for access by operations personnel. Additional safety features could include warning signs and barriers which prevent access by unauthorized persons.

*f. Security.* The design of closure structures must include security provisions which prevent vandalism and the impairment of operating capability. Locked storage facilities which are inaccessible to the public should be provided for the storage of stoplogs, removable posts, and other unsecured parts of closure structures. In areas subject to vandalism, masonry buildings should be used. Latching devices which hold gates in the stored position should be provided with adequate locks.

*g. Construction.*

(1) Procedures and methods. Construction procedures and methods should be considered during design to facilitate the general constructibility of closure structures. All phases of construction and erection procedures, particularly for gated closure structures, should be considered and design details developed which minimize complexities.

(2) Assurance of design integrity. The structural designer must identify, in the project documents, the design assumptions, details, and specifications essential to design integrity. This is necessary to make certain that the closure features receive assurance inspection during construction to verify that actual construction methods are in compliance with the design assumptions, details, and specifications.

*h. Cost comparisons.* The costs of previously constructed closure structures vary according to the closure type and opening size. These variations should be considered in making cost-effective decisions in the selection of the closure type and the design of closure structures for openings in levees and floodwalls of LFPPs.

## Chapter 3

### Selection of Closure Types

#### 3-1. Facilities Requiring Closures

Closure structures are required at openings in levee and floodwall systems when facilities such as railroads, roadways, and pedestrian walkways pass through levee and floodwall systems at elevations below the level of protection provided by the project. The widths of openings for these facilities vary depending upon their functional purpose. Openings for railroads and roadways vary from moderate widths (20 to 40 ft) to widths of 100 ft or more. Openings for pedestrian walkways are usually 20 ft or less. The need for closures should be avoided when possible by using ramps or pedestrian overpasses.

#### 3-2. Closure Structure Types

Closure structures for openings in levee and floodwall systems of LFPPs are usually either stoplog or gate type closures. Stoplog closure structures are usually the least

expensive. Gate closure structures are more functional because they can usually be closed and opened quickly and with less effort.

*a. Stoplog closure structures.* Stoplog closure structures usually consist of one or more sets of horizontal aluminum or steel beams, stacked vertically in the closed position. Aluminum stoplogs weigh less than steel stoplogs of the same size but do not have the same strength. For narrow openings, one set of beams or logs may span between support slots constructed at the edge of openings. For wider openings, intermediate, removable support posts are required as shown in Figure 3-1. Seals are not normally attached to the stoplogs; however, plastic sheeting, sandbags, or other available means should be used to reduce leakage through the stoplog closure structure. Storage facilities must be provided for the stoplogs, removable posts, and accessories. When secured areas are available, closure items may be stored on uncovered storage concrete pedestals or slabs; otherwise, a storage building must be provided. Typical details of a stoplog closure structure are shown in Plates 1-2. Advantages and disadvantages of stoplog closure structures are given below.

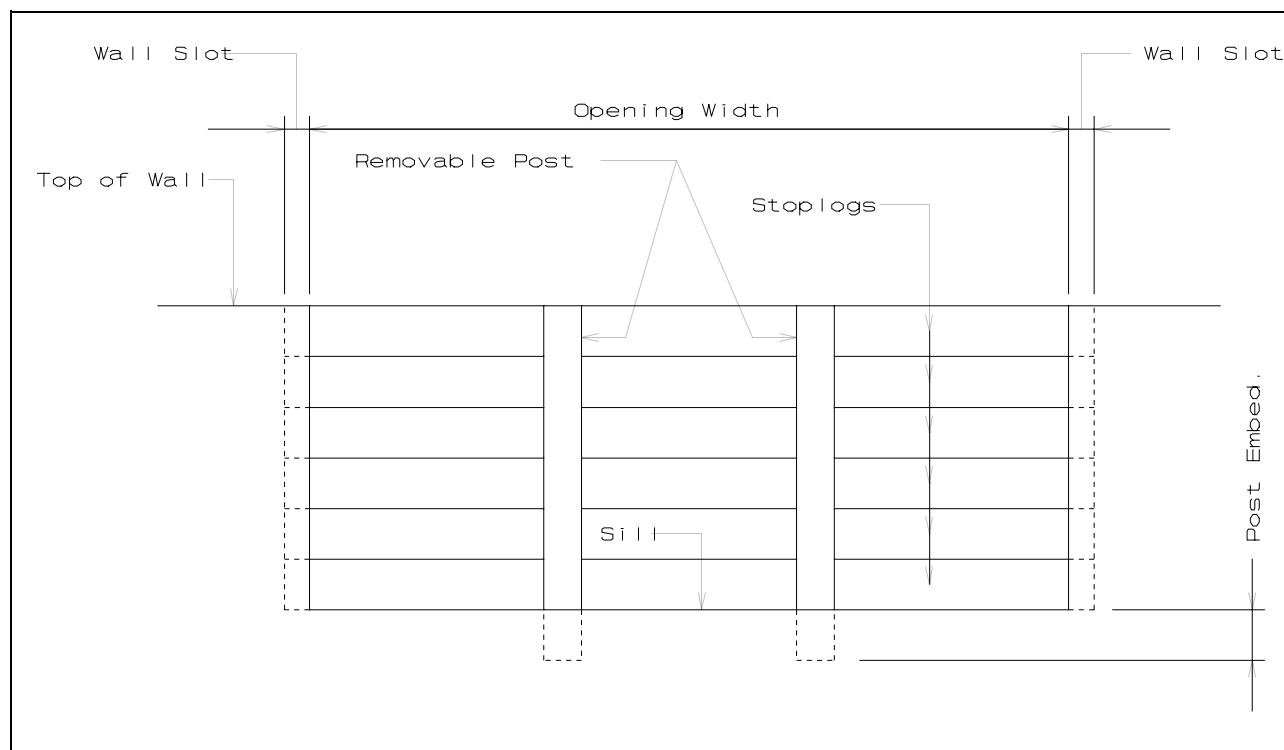


Figure 3-1. Stoplog closure structure

Advantages:

- Fabrication methods are simple and economical.
- Initial cost is usually less than for gate closures.
- Is easily operated for narrow and low openings.

Disadvantages:

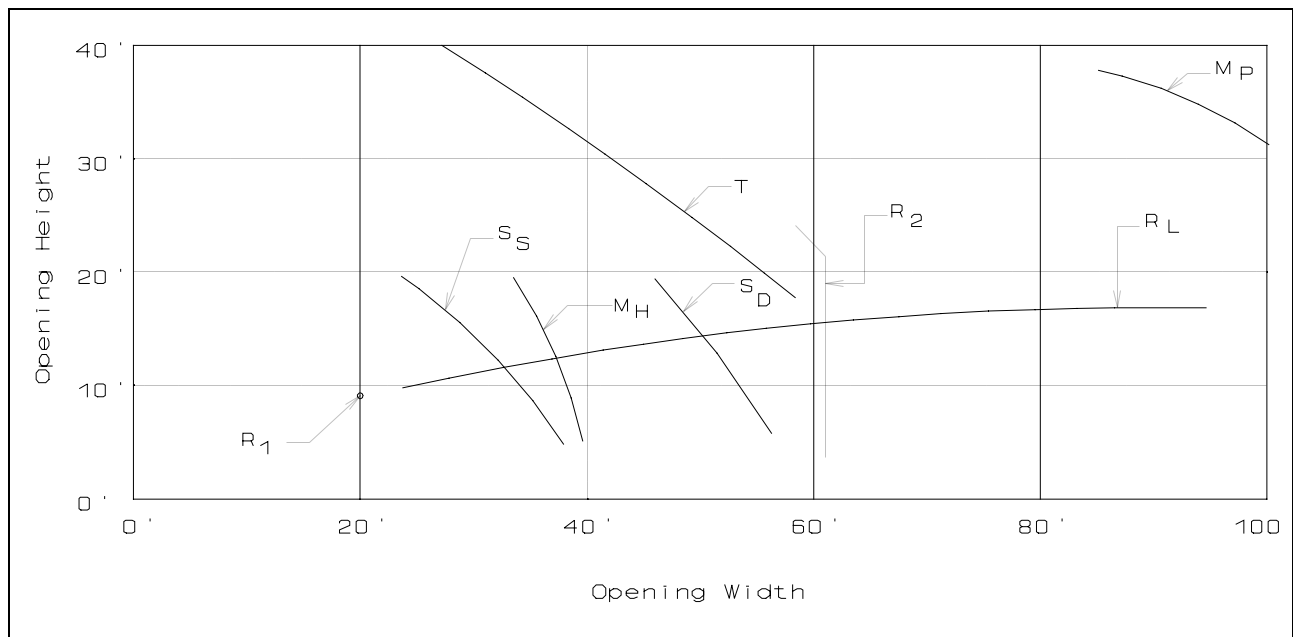
- Intermediate support posts or wide stoplogs are required for wide openings which usually require special lifting equipment for installation.
- Accurate long-range weather forecasting is needed since a relatively long lead time is required to mobilize personnel and equipment for installation.

- Installation time is usually increased to allow cleaning of the post sockets during installation.

- Installation time is longer than required to close gated closures.

- A storage building is required to prevent damage by vandalism or loss by theft.

*b. Gate closure structures.* The most common type of gates used for gate closure structures are swing, miter, rolling, and trolley gates. Figure 3-2 shows outside boundary envelopes for a limited number of gate closure structures from past Corps projects. Gate types are plotted relative to the size of the closure opening. The gate sizes enclosed by the envelopes lie to the left and below the applicable curve or line. Figure 3-2 shows the type of



LEGEND

- $S_S$  = Swing gate, single leaf.  
 $S_D$  = Swing gate, double leaf.  
 $M_H$  = Miter gate with hinges.  
 $M_P$  = Miter gate with pintle, continuous quoin, and miter posts.  
 $R_2$  = Rolling gate stabilized by a double line of wheels.  
 $R_1$  = Rolling gate with a single line of wheels, trolley stabilized.  
 $R_L$  = Rolling gate - L-frame, latch stabilized.  
 $T$  = Trolley gate.

Figure 3-2. Gate type versus opening dimensions

gate and height-to-width relationships used in past designs and is not intended to establish the maximum opening sizes for any particular gate type used in future designs.

(1) **Swing gates.** Swing gates are composed of two or more horizontal girders, vertical intercostals, vertical end diaphragms, a skin plate, and diagonal braces. Swing gates are supported on one side by top and bottom hinges attached to a support structure as shown in Figure 3-3. In most cases, swing gate closures consist of a single swing gate leaf. However, double leaf gates are used for wide openings. Double leaf gates must be stabilized by a removable center post or diagonal tie-back linkages as shown in Figure 3-4. One end of the diagonal linkage rods shall be permanently attached to the free ends of each gate leaf. The other end of the each linkage rod is attached to the support structure when the gates are closed. A support jack is provided beneath the gate to withstand the vertical component of load from the linkage rods. Rubber J-seals are attached to gates to form a continuous water-tight seal between the gates and supporting walls and sill of the opening. Closure provisions should include the use of winches or motor vehicles to accomplish closure during strong winds. Typical details

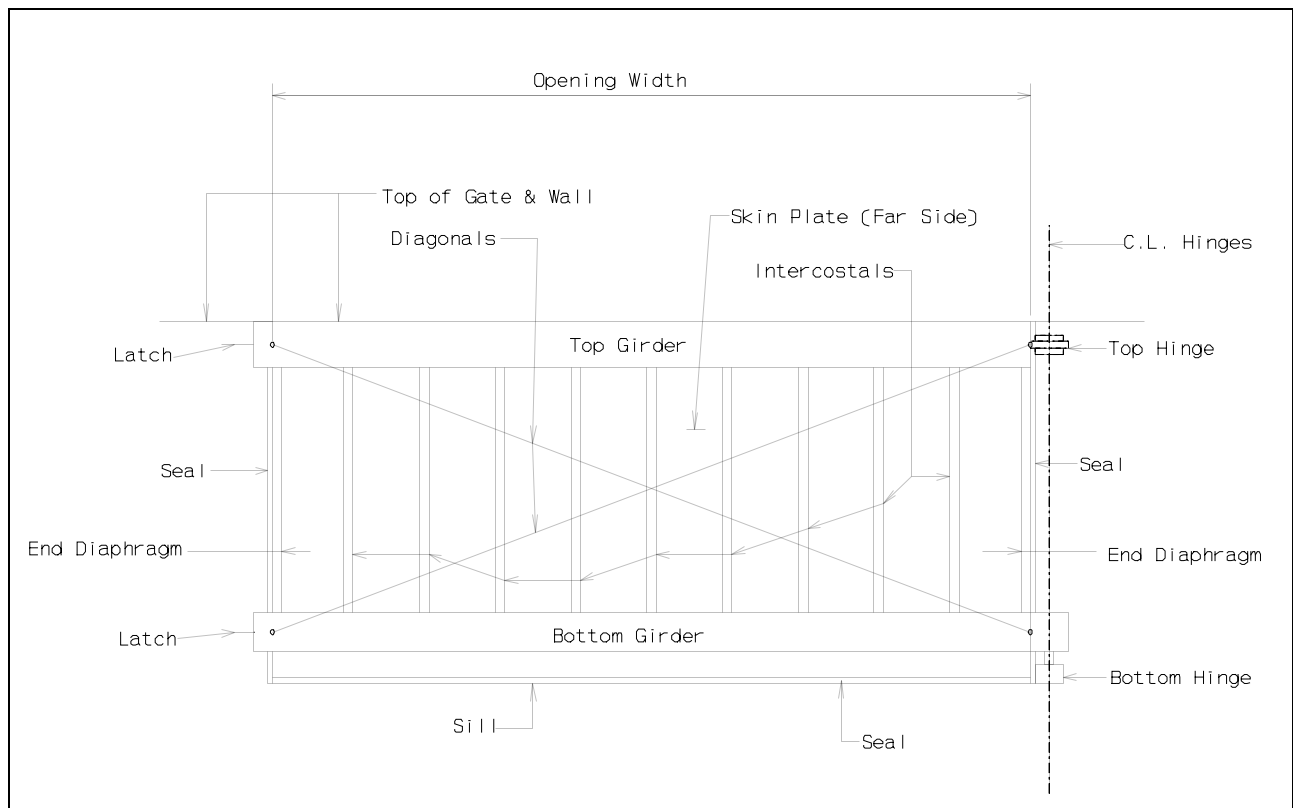
of a swing gate closure structure are shown in Plate 3. Typical details of hinges, seals and latches are shown in Plates 4-12. Advantages and disadvantages of swing gate closure structures are given below.

**Advantages:**

- Single leaf swing gates are more practical for opening widths up to 40 ft.
- Skilled personnel or equipment are not required for operation except when removable intermediate support posts are used with double leaf gates.
- A short lead time is required for making closure except when removable intermediate support posts are used with double leaf gates.

**Disadvantages:**

- Requires right-of-way area for operating.
- Requires complex shop fabrication with machine work.



**Figure 3-3. Swing gate closure structure**



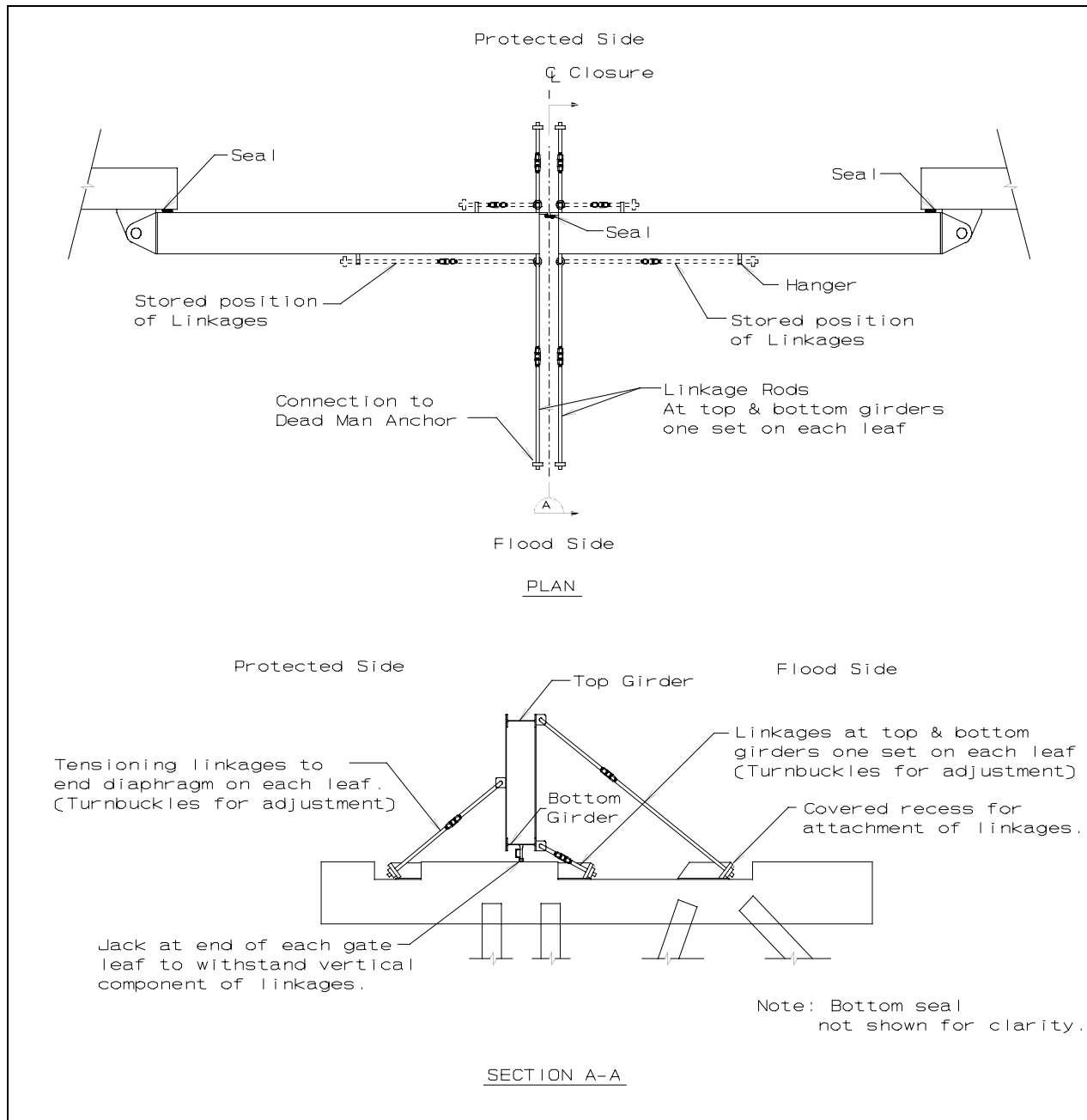
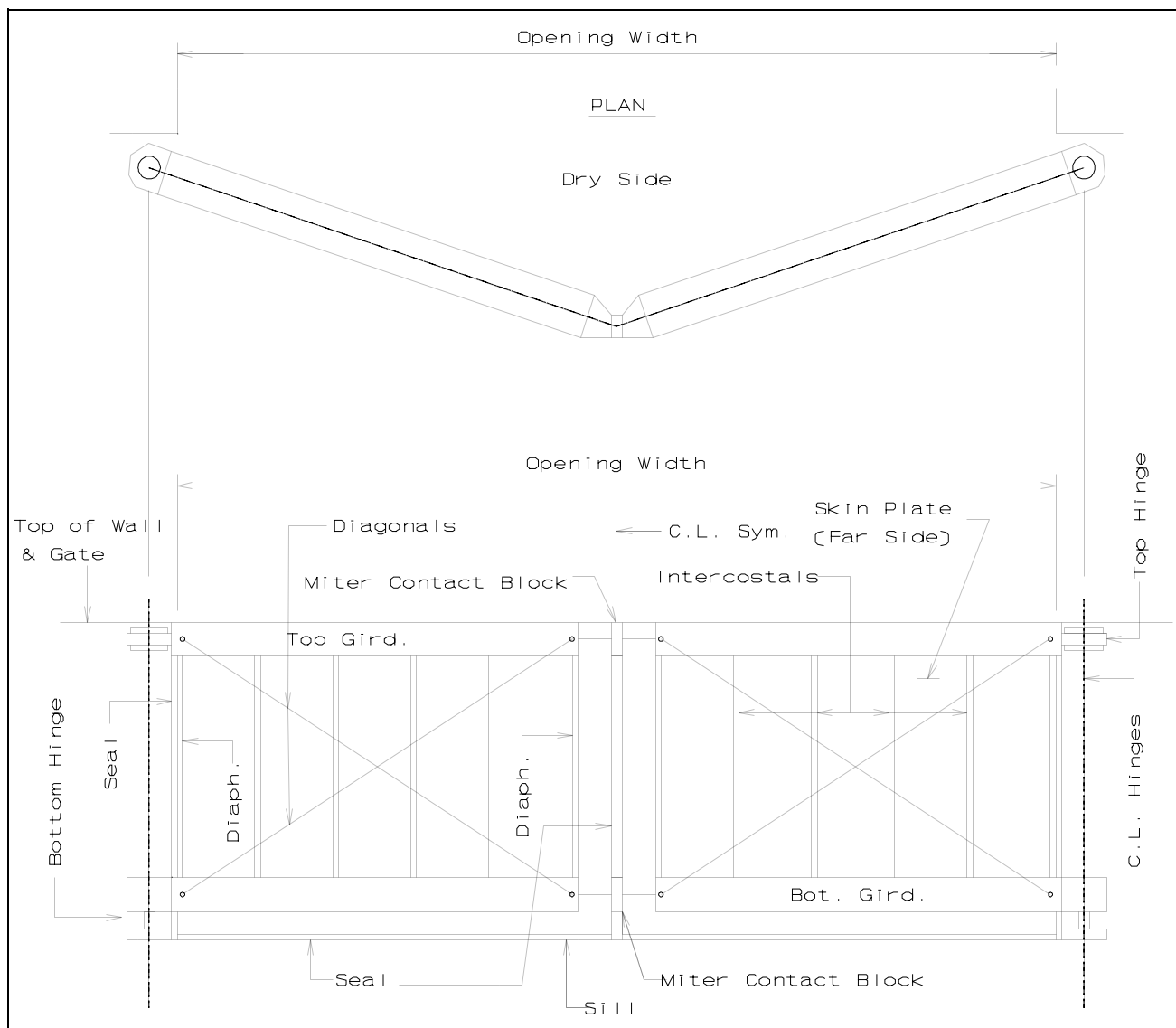


Figure 3-4. Tie-back linkage for double leaf swing gate

- A storage facility is required when removable intermediate support posts are used with double leaf gates.
- Requires a retractable bottom sill to accommodate nonlevel sill surfaces.
- Is difficult to operate during high winds.

(2) Miter gates. Miter gates consist of two leaves that form a three-hinged arch when the gates are in the closed position. Each gate leaf is composed of: horizontal girders, vertical intercostals, vertical end diaphragms, a skin plate, and adjustable diagonal tension rods. The gate leaves are attached to support piers by top and bottom hinges as shown in Figure 3-5. The diagonal tensioning



**Figure 3-5. Miter gate closure structure**

rods are required to prevent twisting of the gate leaves due to their dead load and must be properly tensioned after the gates are installed so that the gates hang plumb and miter properly. Typical diagonal prestressing notes are given in Plate 13. For miter gates with two horizontal girders, the three-hinged arch reactions are resisted by the top and bottom hinges at the supports and spot bearing blocks at the miter ends of the horizontal girders. The magnitude of loading on large miter gates requires the use of three or more horizontal girders, quoin posts with bearings attached to the support piers, and continuous miter posts at the miter ends of the gates to accommodate the forces. Also, hemispherical pintles and top linkages, similar to navigation lock gates, may be required instead

of hinges. Provisions for the design of hemispherical pintles and top linkages are given in EM 1110-2-2703. Hinges and miter blocks or bearing posts must be adjustable to accommodate construction tolerances and allow the gates to miter properly. Support structures for miter gates are usually more difficult to design and cost more than support structures for other types of gates. The supporting structures and their foundations must be designed to minimize the deflections at the gate hinges or quoin posts so that the gates will function as designed. J-seal assemblies are provided for water tightness. Latches are provided to secure the gates in the stored and closed position. Seal, hinge, and latch details for miter gates are similar to those used for swing gates. Closure

provisions should include the use of winches or motor vehicles to accomplish closure during strong winds. Typical details of a miter gate closure structure are shown in Plates 14-16. Advantages and disadvantages of miter gate closure structures are given below.

Advantages:

- Is suitable for large openings.
- Closure can be made quickly without the use of skilled personnel.
- A storage building is not required.
- Weighs less than other types of gates designed for large openings.
- A center support is not required.

Disadvantages:

- Requires complex shop fabrication with machine work.
- Requires right-of-way area for operating.
- Support structure is more complex to design and more expensive than for other gate types.
- Requires a retractable bottom seal to accommodate nonlevel sill surfaces.
- Is difficult to operate during high winds.

(3) Rolling gates. Rolling gates are composed of a structural steel frame covered with a water barrier skin plate. The gates are supported by wheels that roll on tracks embedded in the sill across the closure opening and the storage area. J-seals are attached to the ends and bottoms of the gates to form a water-tight seal between the gates and the plates embedded in the end supports and the bottom sill. The gates are sometimes operated by a cable attached to a truck motorized winch; however, the cable could also be connected directly to a truck which pulls the gate open or closed. Alternately, the design may consist of a winch mounted at the site for gate operations. Gates along fast rising streams may be designed to be opened or closed from the protected side of the floodwall as shown in Plates 17-20. Latches should be provided to secure the gates in the stored and closed positions.

(4) Rolling gate - stabilized with two lines of wheels. Rolling gates stabilized with two lines of wheels are composed of: horizontal girders, vertical intercostals, vertical end and intermediate plate diaphragms, a skin plate, and two lines of support wheels as shown in Figure 3-6. The wheels support and stabilize the gate against overturning. The wheels are usually V-grooved castings and roll on tracks that are usually inverted angles with embedded anchorages. The depth of the bottom girder is usually governed by the required transverse spacing between the supporting wheels rather than the hydrostatic load. A girder depth of 30 to 36 in. is normally required to accommodate the spacing between the two lines of wheels to provide stability of the gate during opening and closing operations. Typical details of a rolling gate stabilized with two lines of wheels are shown in Plate 21. Advantages and disadvantages of rolling gates stabilized with two lines of wheels are given below.

Advantages:

- Is adaptable to wide openings.
- Closure can be made quickly without the use of skilled personnel.
- A storage building is not required.
- Requires small storage space.

Disadvantages:

- Requires a retractable bottom seal to accommodate nonlevel sill surfaces.
- Unless wheel assemblies are designed to accommodate the lateral bottom girder deflection, jacks must be provided to lift the wheel assemblies from the tracks when the gate is in the closed position.
- Requires level storage area immediately adjacent to the closure opening.

(5) Rolling gate - with single line of wheels and stabilizing trolleys. These gates are usually composed of a trussed steel frame covered with skin plate or bridge planks. The gates are supported at the bottom by a single line of wheels and are stabilized laterally by an extended top girder supported by trolleys attached to the top of the floodwall as shown in Figure 3-7. Girder depths are usually governed by the hydrostatic loading on the gate.

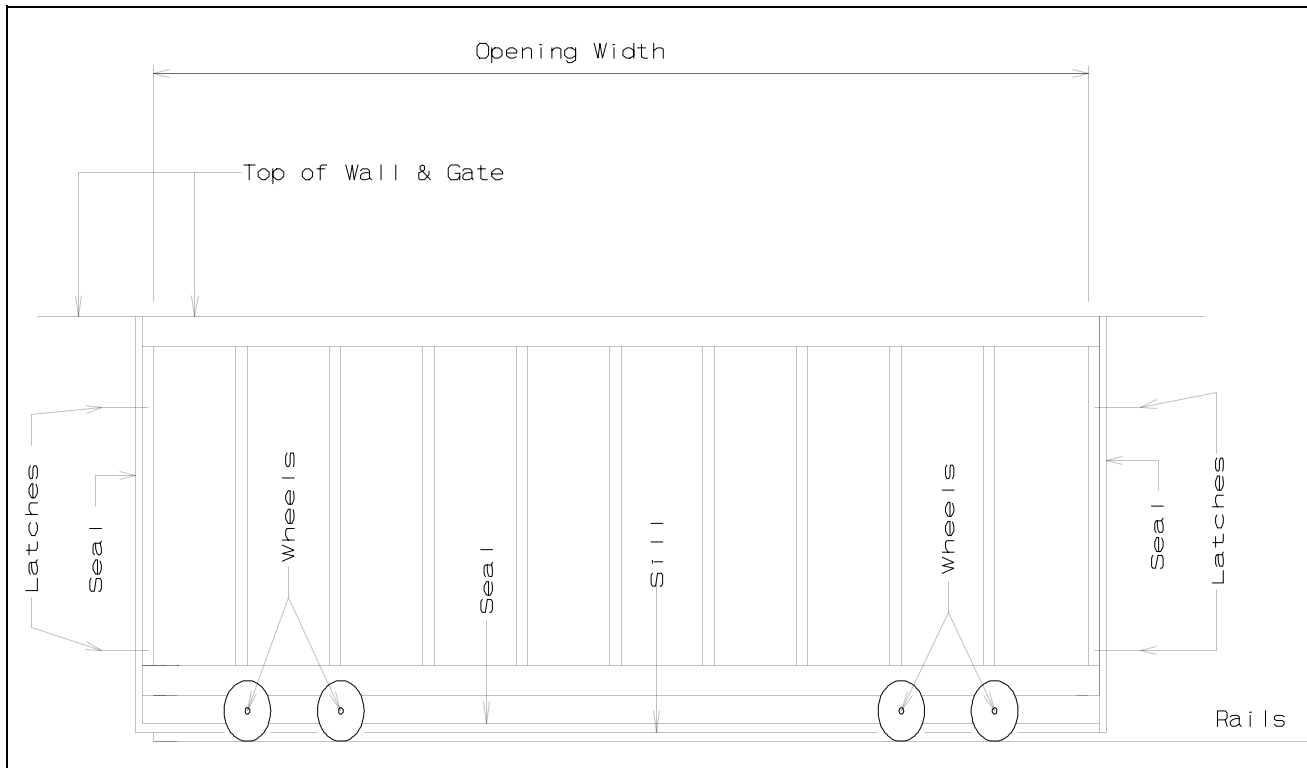


Figure 3-6. Rolling gate - stabilized with two lines of wheels

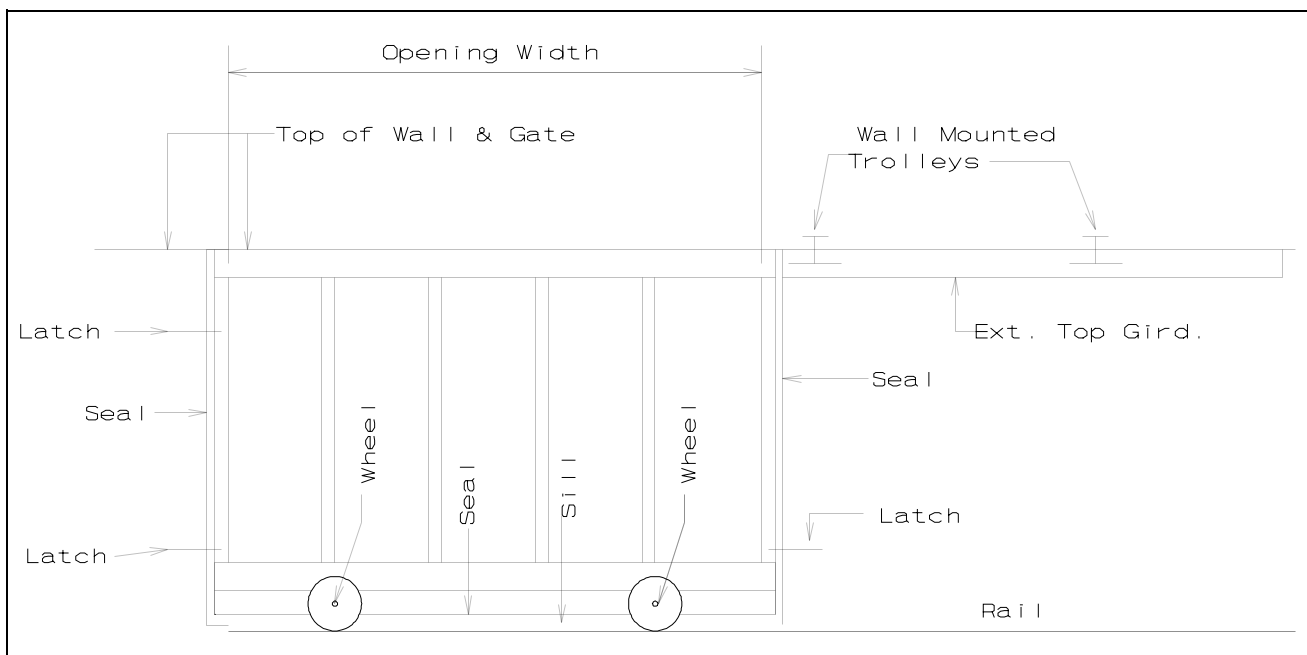


Figure 3-7. Rolling gate - single line of wheels and stabilizing trolleys

Typical details of a rolling gate with a single line of wheels and stabilizing trolleys are shown in Plate 22. Advantages and disadvantages of rolling gates with a single line of wheels and stabilizing trolleys are given below.

Advantages:

- Is practical for closure widths up to 30 ft.
- Closure can be made quickly without the use of skilled personnel.
- A storage building is not required.
- Requires small storage space.

Disadvantages:

- Requires a retractable bottom seal to accommodate nonlevel sill surfaces.
- Requires level storage area immediately adjacent to the closure opening.

(6) Rolling gate - L-frame. These gates are usually composed of a series of L-shaped structural steel frames interconnected by horizontal and diagonal members. The gates are supported at the bottom by two lines of wheels as shown in Figure 3-8. Hooks attached to the heel of each of the L-frames engage anchorages embedded in the concrete sill structure to stabilize the gate against hydrostatic loadings. Typical details of an L-frame rolling gate are shown in Plate 23. Advantages and disadvantages of L-frame rolling gates are given below.

Advantages:

- Can be designed for any opening width.
- Can be shop-fabricated in sections to simplify handling and storage.
- Closure can be made quickly without the use of skilled personnel.
- A storage building is not required.

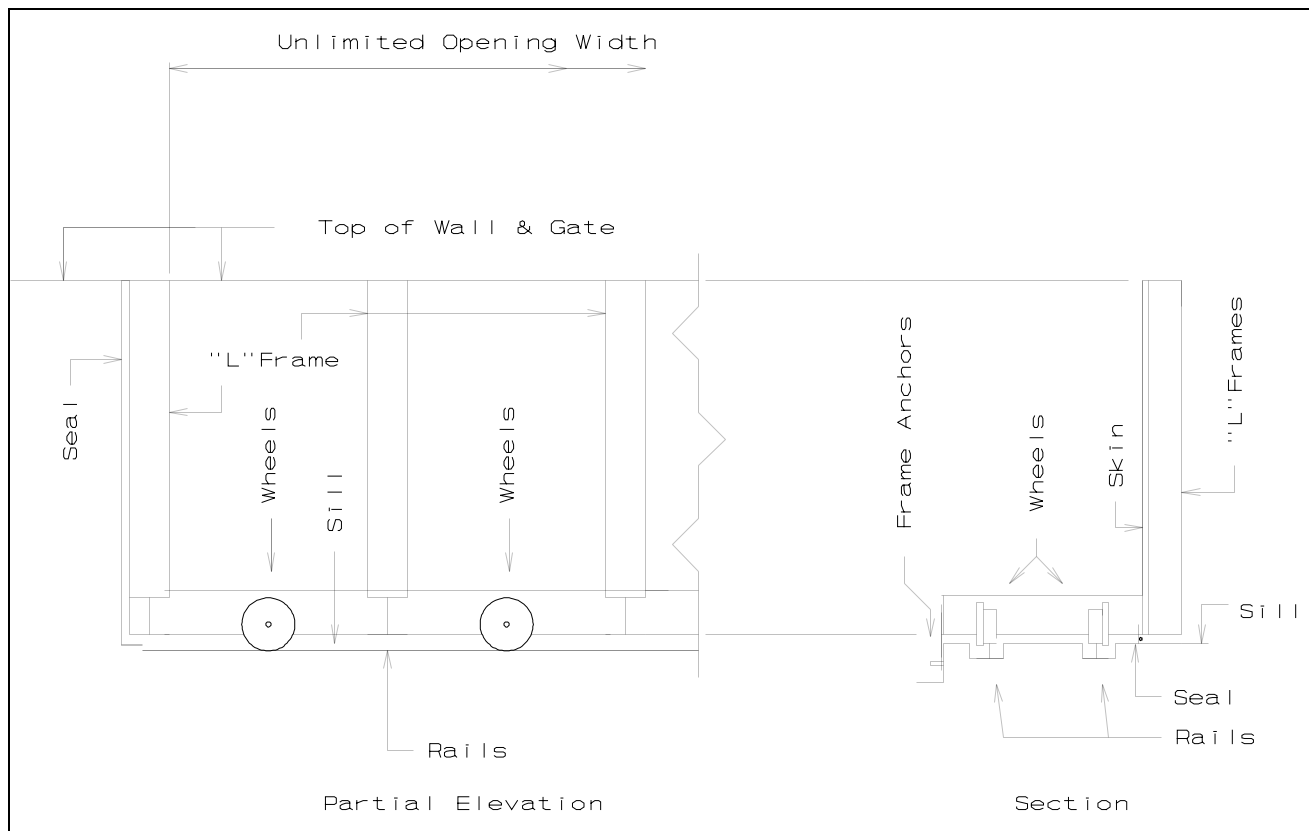


Figure 3-8. Rolling gate - L-frame stabilized by hooks

- Requires small storage space.

Disadvantages:

- Requires a retractable bottom seal to accommodate nonlevel sill surfaces.
- Requires level track surface.
- Requires level storage area immediately adjacent to the closure opening.
- Requires wide sill to accommodate the installation of tracks and hook anchorages.

(7) Trolley Gates. Trolley gates are usually composed of top and bottom horizontal girders, other secondary framing members, and a skin plate. Trolley gates are suspended from trolleys running on an overhead rail and beam supported by the floodwall as shown in Figure 3-9. The gates are opened and closed by a winch arrangement

similar to that used for rolling gates. Typical details of a trolley gate closure structure are shown in Plate 24. Advantages and disadvantages of a trolley gate closure structure are given below.

Advantages:

- Is practical for closure widths up to 60 ft.
- Closure can be made quickly without the use of skilled personnel.
- Can obtain a good seal against irregular sill surfaces.
- A storage building is not required.
- Requires small storage space.
- Is suitable for railroad closures because required vertical clearances for railroads are fixed.

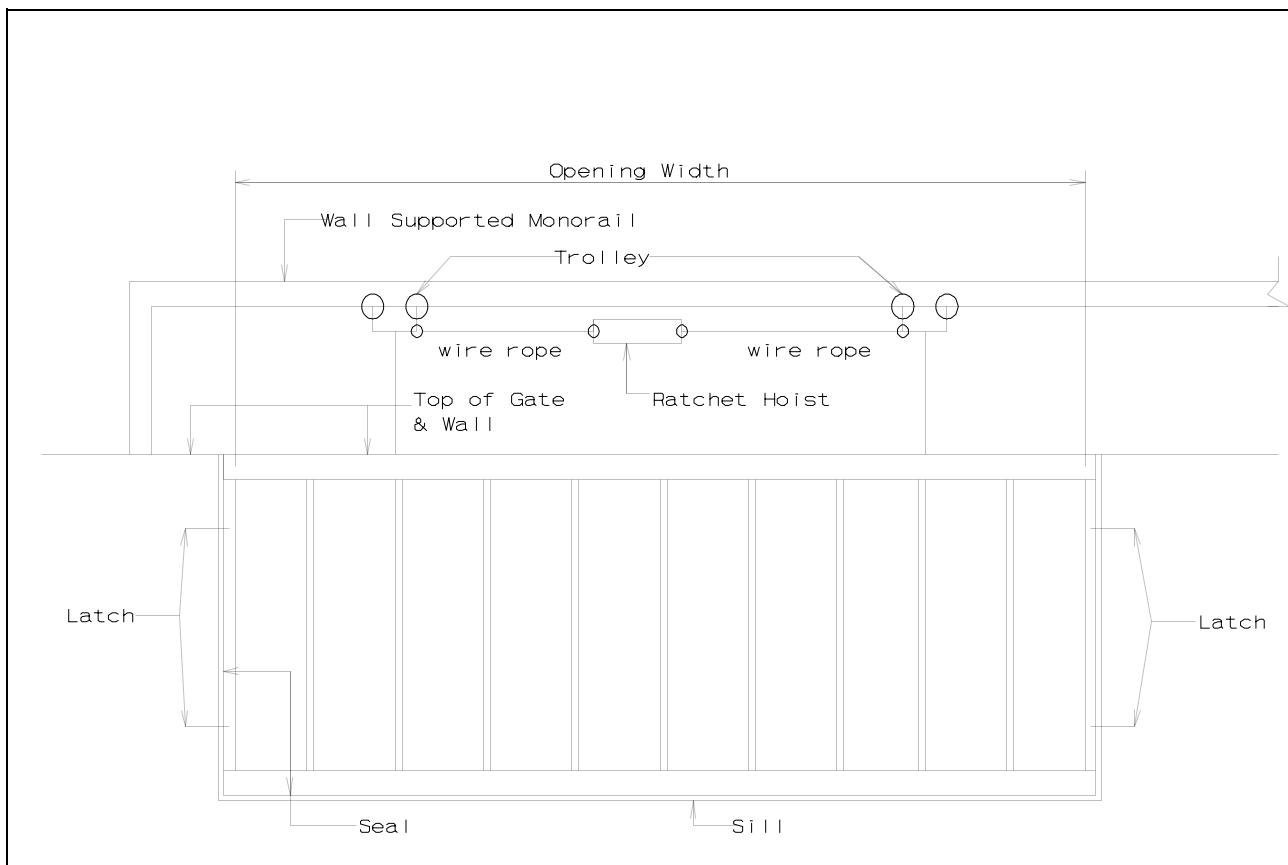


Figure 3-9. Trolley gate

Disadvantages:

- Slope of the ground adjacent to the closure opening must allow adequate clearance to open the gate.
- May be rendered inoperative due to permanent overhead support members being damaged by vehicles or other sources, or removable overhead support members or their anchorages being damaged during removal or placement operations.

- A guide member at the base of the gate may be required to support the gate against wind loads during opening and closing operations.

*c. Prefabricated stoplogs and gates.* Prefabricated stoplogs and gates are commercially available and are usually more cost effective for closure structures with small openings.

## Chapter 4 Structural Analyses and Design

### 4-1. Stress Criteria

*a. Concrete.* Criteria for the design of reinforced concrete elements of the closure structures are given in EM 1110-2-2104.

*b. Structural steel.* Criteria for the design of structural steel closure gates shall be based on the provisions given in EM 1110-2-2105. Design for the normal (usual) load cases shall limit the allowable stress to 5/6 of the allowable given in AISC (1986). This "5/6" modification factor is used because Corps criteria require a higher safety factor for hydraulic structures than AISC uses for building design. Allowable stresses 1/3 greater than the normal stresses shall be used for load cases that include water to the top of the closure, wind, earthquake, or short duration loads. Load and resistance factor design criteria for structural steel closure gates are provided in EM 1110-2-2105 and AISC (1986).

*c. Structural aluminum.* The design of aluminum shall be based on the provisions of the Aluminum Association (1986). The allowable stress shall be limited to 5/6 of the basic values given therein for normal load cases. This allowable stress should be increased by 1/3 for design cases that include water to the top of closures, wind, earthquake, or short duration loads.

### 4-2. Loading Criteria

Load cases I1 through I4, given in Chapter 4 of EM 1110-2-2502 for the design of inland flood walls, shall be used for the design of closure structures. An additional load case, Case I5, is included for the design of the gate hinges and support structure for swinging gates. These load cases are described below. Load cases for closure structures loaded in coastal areas are given in Table 4-3 of EM 1110-2-2502.

*a. Case I1, Design flood load.* Closure in the closed position; water level on the unprotected side at the design flood level (top of wall less freeboard); water level on the unprotected side at or below the gate sill elevation.

*b. Case I2, Maximum flood load.* Same as Case I1 except water level is at the top of the closure on the unprotected side.

*c. Case I3, Earthquake load.* Water level at the usual water elevation during the nonflood stage; earthquake-induced lateral and vertical loads are acting. (Note: This case is applicable to support structures only.)

*d. Case I4, Short-duration loading.* Closure is subjected to short-duration loads with the gate in any position. The gate should be designed for a wind load of 15 psf during opening and closing and for a wind load as specified in EM 1110-2-2502 when the gate is in the closed position. Other special loads may be necessary for closures in hurricane flood structures to ensure safe operation during gate closures. For example, gates could be subjected to storm wave loadings during gate closing operations if gate closure is delayed as long as possible to allow for the movement of railway traffic during a storm.

*e. Case I5, Gate swinging.* Hinged gate of a gate closure in any position; subjected to dead load only.

### 4-3. Design Analysis Criteria

The design analysis criteria for closure structures are presented in detail in the design examples included in Appendices B through F. Provisions for designing and determining the stability of supporting posts, walls, and sills of closures are not included in this guidance. Chapters 4 and 5 of EM 1110-2-2502 should be referred to for overturning and sliding stability requirements. Flotation criteria are given in EM 1110-2-3104. The design of pile foundations should comply with the criteria in EM 1110-2-2906.



## **Chapter 5**

### **Appurtenant Components**

#### **5-1. Gate Operating Equipment**

Gate operating equipment includes motorized vehicles, winches, latches, wire rope, hooks, sheaves, snatch blocks, and other appurtenances. These items should be provided as prescribed herein and as needed for the operation of closure structures.

#### **5-2. Seal Assemblies**

Rubber seals should be of the type suitable for the particular application. Seal assemblies should be designed to fit

the configuration of the gates and gate sills. Hinged bottom seal assemblies, similar to the details shown in Plate 10 are adaptable to uneven or broken sill configurations. This seal assembly is raised to clear the roadway grade during gate movements to prevent damage to the rubber seals.

#### **5-3. Embedded Metals**

Embedded structural steel bearing plates and anchorages must be provided as required for the installation of gates and appurtenances. Embedded seal plates shall be galvanized steel, stainless clad steel, or solid stainless steel for the prevention of corrosion. The edges of embedded seal plates should extend approximately 2 in. beyond the sealing surface.

## **Chapter 6**

### **Corrosion Protection**

#### **6-1. Criteria**

Criteria for corrosion protection of metals are given in EM 1110-2-21-5 and EM 1110-2-3400.